Delta Blues, California Style

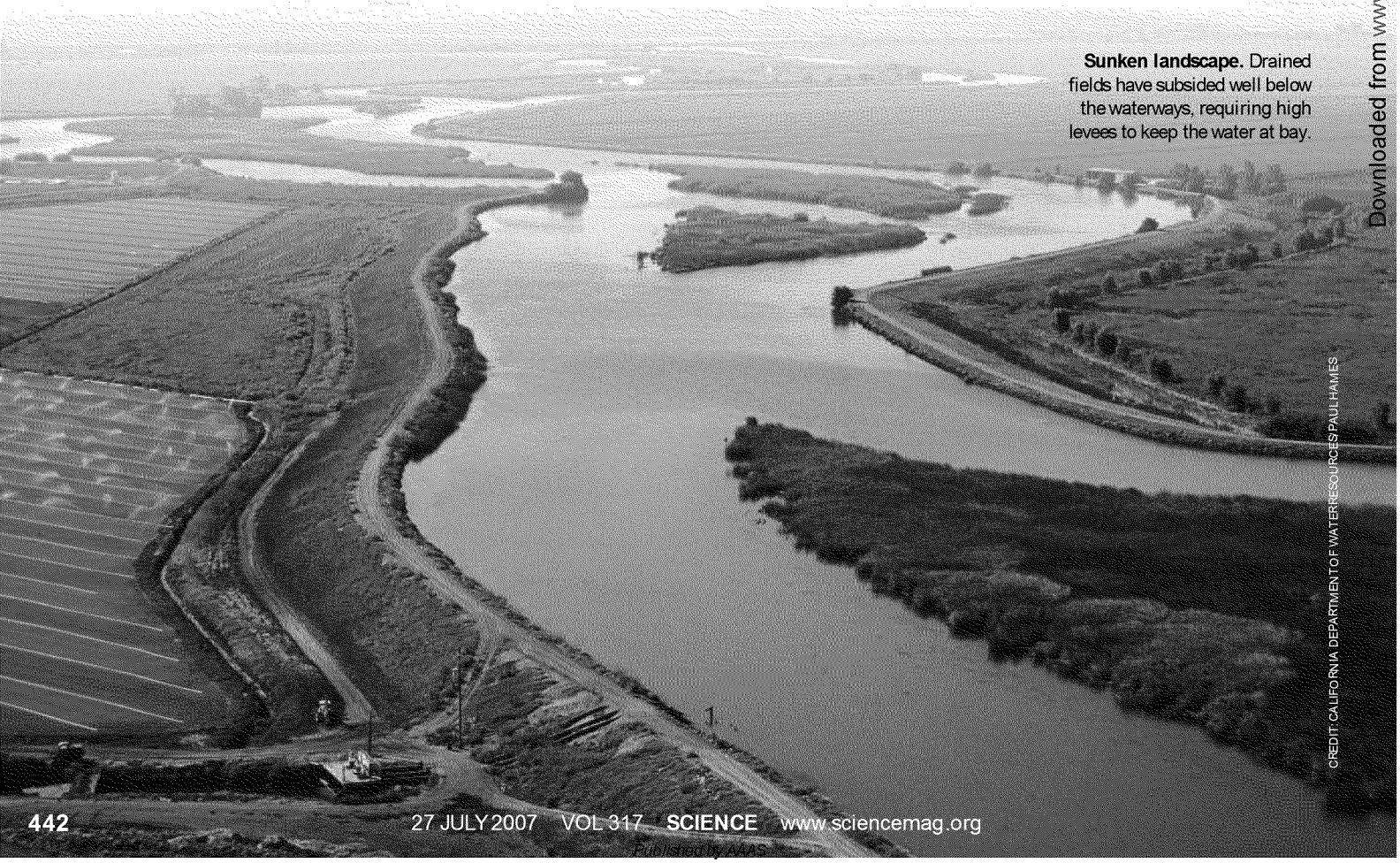
The hub of California's freshwater system is plagued by crashing fisheries, high demand, invasive species, and pollution—and a major earthquake there could devastate the state's drinking water and agriculture

BYRON, CALIFORNIA—In a makeshift laboratory that was once a refrigerated shipping container, Joan Lindberg, a research biologist at the University of California (UC), Davis, shines a small flashlight into a 2-meter-diameter water tank. Two-centimeter pencil-thin fish known as delta smelt dart away from the light. These small fish, native to the Sacramento–San Joaquin River Delta that flows just beyond these tanks, are bred and farmed out to fisheries biologists throughout the region who are racing to understand their life cycle, feeding habits, and vulnerabilities. It's a race that's now in full sprint, as the population of delta smelt in their native habitat is in free fall.

Historically, millions of the fish swam this delta, which sits just east of San Francisco Bay and is the largest estuary on the West Coast of the United States. But a survey of juvenile smelt conducted in June found only 37, down from 884 found a year earlier. More than 700 smelt were killed this spring by a series of massive pumps nearby that suck a river's worth of water out of the delta and send it south to Los Angeles and San Diego. But the water exports are only one of the smelts' problems, with pollution and invasive species also topping the list of concerns. Now, with the delta smelt teetering on the edge of extinction, Lindberg and her colleagues are looking into ramping up their fish-breeding efforts to try to prevent the fish from going extinct. "We're doing what we feel is prudent to save the wild fish," Lindberg says.

More than a kilometer up the road, a second set of massive pumps sucks out another river's worth of water and sends it primarily to farmers in California's Central Valley. Here, as technicians survey fish caught in a mesh bucket designed to pull fish from the water before it's sent to the pumps, they look intently for smelt and other endangered fish. Today, no delta smelt are among the dozens of striped bass, catfish, and other fry caught. But one was snagged just days earlier, which was enough to send shudders through this farming community. "What comes out of that bucket can determine the economic fate of California's cities and farms," says Jeffrey McCracken, a spokesperson for the U.S. Bureau of Reclamation (BOR), the federal organization that runs the Central Valley Project pumps.

The comment may sound hyperbolic, but it's not. Twenty-five million Californians, nearly two out of every three, depend on the delta for at least some portion of their drinking water. Central Valley farmers, the heart of America's vegetable, fruit, and nut production, are even more dependent, as the delta provides irrigation for about 1 million hectares of farmland. And although water from the delta has flowed to these users for



Sunken landscape. Drained fields have subsided well below the waterways, requiring high levees to keep the water at bay.

CREDIT: CALIFORNIA DEPARTMENT OF WATER RESOURCES/PAUL HAMES

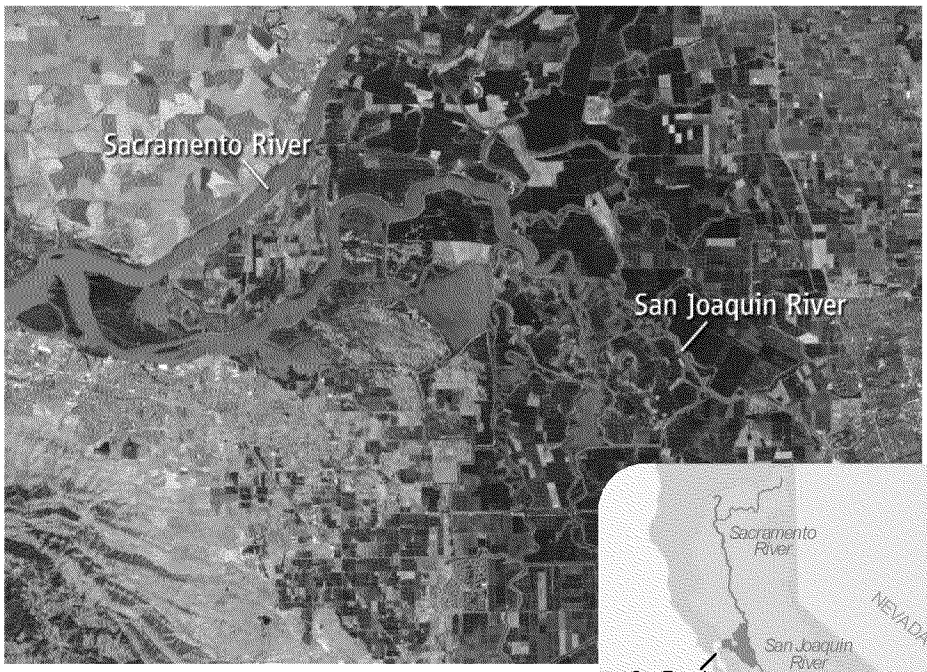
decades, that might not always be the case. In May, citing the U.S. Endangered Species Act and the hundreds of delta smelt killed at the State Water Project pumping facility nearby, a California Superior Court judge ordered the pumps shut down for 10 days, a rare move that fired a shot across the bow of water managers statewide. "This is a very important wake-up call for California," says Lester Snow, head of California's Department of Water Resources.

But the smelt is only the delta's most immediate concern. Several other fish species native to the delta are also in steep decline, also battered by loss of habitat, pollution, and competition from hundreds of invasive species. Rising sea levels prompted by climate change threaten to push salt water from San Francisco Bay much farther inland, possibly even overwhelming the southern delta region where fresh water is drawn for people and irrigation. Finally, the delta is home to a labyrinth of 1770 kilometers of earthen levees designed to channel the delta's water on its way to the bay. Those levees, some 130 years old, sit near six seismic faults that crisscross the region, and it's widely feared that a major quake could produce catastrophic levee failures that would wipe out water supplies for tens of millions of people (see sidebar, p. 444).

"The delta is a mess," says Phillip Isenberg, who chairs the Delta Vision Blue Ribbon Task Force appointed by California Governor Arnold Schwarzenegger last year to come up with potential solutions for the delta. At a congressional field hearing on the delta in Vallejo, California, earlier this month virtually all the participants agreed with Isenberg that the Bay Delta is in crisis and the way it is currently managed is unsustainable. Now, Isenberg says, Californians must make some hard choices concerning competing interests for the water, municipalities, farms, and the environment being among them. "If we do not make these difficult choices, then extinction—whether of a species or a way of life—may be the water policy of California," said Isenberg in written testimony.

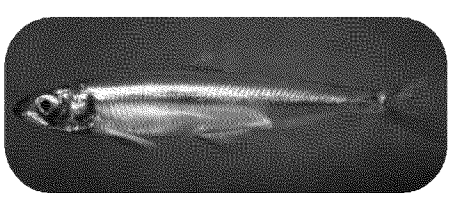
Changing tides and rivers

It's a problem that's been brewing for a long time. The Sacramento–San Joaquin River Delta is the hub of California's water system. It's an expansive inland river delta comprising 300,000 hectares of land interlaced with hundreds of kilometers of waterways. Historically, those waterways shifted course seasonally as water draining from the northern Sierra flowed down into neighboring San Francisco Bay. That began to change shortly after settlers flocked to the region in the gold rush of the 1840s and 1850s. In 1869, farmers began draining and diking land within the delta, ultimately creating a patchwork of some 65 "islands." However, unlike natural islands that rise above the surrounding water, the delta's islands are actually vast bowls ringed by levees to keep the water at bay. Over time, this challenge of holding back the tidal waters has steadily increased, as exposure of the former mud flats to the air has oxidized and compacted the peat-rich soils, causing central farmlands within the delta to subside a full 6 to 8 meters below sea level. Delta farmers have responded by building their levees higher, fully engineering some of the breakwaters but simply creating giant mounds of dirt with most of the others.



Changed delta. Landsat image shows the delta's patchwork of sunken islands surrounded by hundreds of kilometers of waterways.

The levees were only the first of major changes to the delta. With the levees in place, farmers within the delta itself began siphoning off roughly 1 million acre-feet (1.2 billion cubic meters) of water per year, enough to provide the yearly water supply for roughly 2 million California families. As California's population boomed in the early 20th century, other users eyed the delta's abundant water. Beginning in 1951, a series of five massive pumps at the C. W. Jones Pumping Plant began taking out water for Central Valley farmers and nearby communities. Early on, the Central Valley Project typically pulled out around 2 million acre-feet of water per year. But over time, that number has risen to around 3.3 million acre-feet (4 billion cubic meters) of water per year. Meanwhile, withdrawals by the State Water Project, which sends water to southern California, have risen from about 1 million acre-feet (1.2 billion cubic meters) per year in 1968 to 4.2 million acre-feet (5.2 billion cubic meters) per year today. In a dry year, those diversions can amount to about one-third of all the water that would normally flow through the delta into San Francisco Bay. The draw from the pumps is often so great that some river channels through the delta actually flow backward, upstream toward the pumps at a pace too brisk for the smelt and other weak swimmers to escape.



Barely hanging on. The delta smelt, once prolific, is now endangered.

Not everything in the delta is on its way out. More than 200 invasive species now make the delta the most invaded estuary in the world. The invaders, including everything from striped bass to a fast-growing

CREDITS (TOP TO BOTTOM): ROBERT SIMMON/NASA; B. MOOSE PETERSON/U.S. FISH AND WILDLIFE SERVICE

Published by AAAS

aquatic weed known as *Egeria*, have markedly changed the delta's habitat. Urban development is also on the rise and is expected to add another 130,000 homes in the region over the next decade and more than double the region's population to 7.7 million by 2050. And pollution from urban runoff, sewage, and agricultural chemicals has also been growing steadily.

That combination has challenged fish populations for decades. Of the delta's 29 native fish species, 12 either have been eliminated entirely or are currently threatened with extinction. Today, the delta smelt's plight is forcing the issue, in part because it is seen as an indicator species for the health of the delta in general, much as the northern spotted owl's numbers served as a proxy for the health of old-growth forests in the 1980s and 1990s.

But an initial round of crises took shape in the early 1990s, when Chinook salmon and other fish species were found to be in sharp decline. Litigation by environmental groups and requirements under the Endangered Species Act triggered shutdowns of the water project pumps, water supply cutbacks, and widespread complaints that the federal and state agencies were often working at cross purposes with one another.

In hopes of finding a way out, federal and state leaders forged a collaborative research and decision-making process known as CALFED to try to create a common vision for improving the delta. The effort was widely heralded for bringing more than 100 local, state, and federal government agencies that have jurisdiction over some aspect of the delta and its wildlife together with stakeholder groups such as farmers, industry representatives, and environmentalists. But because those stakeholders were unable to agree on major changes to the delta, CALFED leaders focused their efforts on creating a robust science program for studying the delta, initiating numerous habitat restoration projects, and developing a market-based system to pay farmers upstream from the delta to forgo water diversions in order to keep the water in stream for fish.

Although CALFED's science program in particular has largely been viewed as successful in creating a vast knowledge base on which to base ecological decisions, recently the collaborative process has begun breaking down. Ultimately, the delta's problems stem from the fact that there isn't enough water to satisfy all the competing users, Isenberg

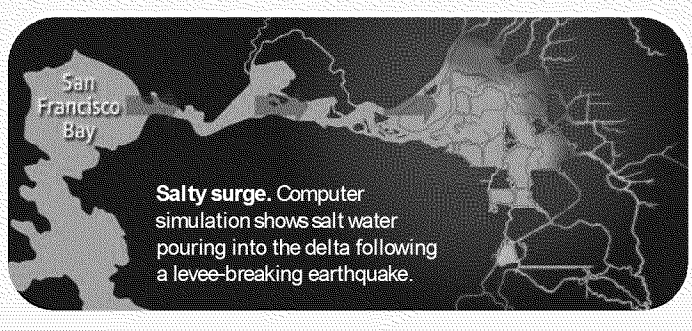
Shaky defenses. A break in a levee near Holt in June 2004 sent water pouring into fields and workers scrambling to shore up nearby levees.

FROM CRISIS TO CATASTROPHE

If and when the earth begins to shake along one of six major seismic faults in and around the Sacramento–San Joaquin River Delta, the fate of the small, threatened delta smelt will no longer be the region's biggest problem. The delta is laced with more than 1700 kilometers of earthen levees, many of which would likely breach in a major flood or quake. The results could make the devastation wreaked by Hurricane Katrina look tame by comparison. The system of delta levees, says Jeffrey Mount, a geologist at the University of California, Davis, "is in much worse shape than anybody thought."

In 2005, Mount and his Davis colleague Robert Twiss reported that over the next 50 years there is roughly a two in three chance that a combination of seismic activity and increased flooding from climate change would produce a catastrophic failure of multiple levees in the delta. Those levees surround farmland where the earth has subsided up to 8 meters in many cases. If the levees collapsed due to a quake during a period of low freshwater flows through the delta, water to fill the 2.5 billion cubic meters of space in the island basins would be pulled in from San Francisco Bay and Suisun Marsh at the mouth of the delta, drastically altering the freshwater habitats and likely forcing the shutdown of massive pumps that carry delta water to Central Valley farmers and millions of residents in southern California. According to a new analysis by the California Department of Water Resources, repairs could top $30 billion and take from 1.4 to 6.4 years depending on the extent of the damage. Indirect costs to communities that would lose access to water from the delta could exceed $50 billion.

Last year, California voters passed a bond measure making roughly $1 billion available for delta levee repairs and improvements. Mount calls this "a nice start" that should help bring some of the older levees up to the most basic federal guidelines but adds, "they are sitting on poor foundations and will be unstable in an earthquake." The truth is, Mount says, the economic fate of millions of Californians currently depends on a maze of dirt piles that could easily give way with a little shove from nature. **–R.F.S.**



Salty surge. Computer simulation shows salt water pouring into the delta following a levee-breaking earthquake.

CREDITS (TOP TO BOTTOM): AP; CALIFORNIA DEPARTMENT OF WATER RESOURCES

Published by AAAS

says. And CALFED lacked the political clout to choose winners and losers. "I think it has done all it can do that isn't controversial," says Lois Wolk, a Democratic California State Assembly member from the delta region west of Sacramento who has closely followed delta issues.

A return to the courts

About the only thing that isn't controversial these days is the fact that delta smelt's numbers have plummeted, along with those of the area's other pelagic fish, which spend at least part of their life cycle in the ocean or in brackish estuaries. But just what is causing the crash isn't as obvious. According to the report released in March by a collection of state and federal water agencies known as the Interagency Ecological Program (IEP), the culprits likely include impacts from pollution, invasive species, and water exports. Among the specific concerns, the IEP reported that agricultural pesticides known as pyrethroids have been shown to be acutely toxic to aquatic life, and their use has more than doubled to over 115,000 kilograms per year in the delta, in part to combat noxious aquatic weeds. Of the exotics, one of the most worrisome has been the Asian clam, a filter feeder that consumes phytoplankton. Those phytoplankton are the primary food source for zooplankton, which in turn are a primary food source for the delta smelt.

With the delta smelt's numbers in steep decline, and CALFED's inability to force major changes, environmental groups have returned to the courts. "Litigation has ousted collaboration as the dominant means of solving water issues," says David Nawi, an attorney with Environmental Mediation in Sacramento, California. Last year, a trio of environmental groups challenged the U.S. Fish and Wildlife Service's (USFWS's) 2004 biological opinion, which outlines the agency's strategy for protecting the species. Among other things, they argued that the agency failed to cite the best available science by not using the latest surveys of smelt abundance and not taking climate change into account. On 25 May, a federal judge agreed, tossing out the old biological opinion and forcing a rewrite, which is expected next year. Just what remedies the judge will order in the meantime is scheduled to be decided next month, and court cases on other threatened species and challenges to delta-area development also remain in the works.

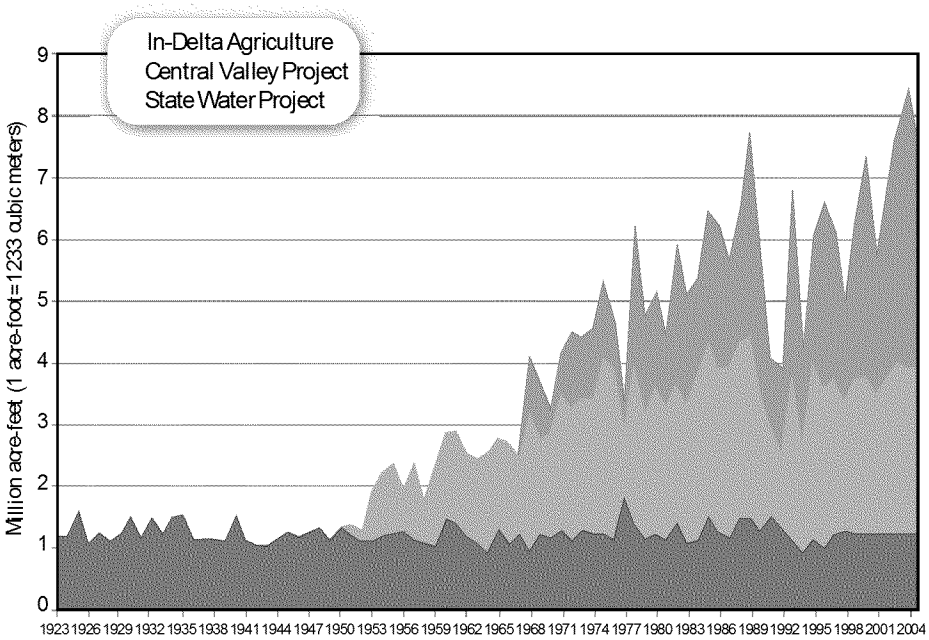
According to attorney William Stelle, a veteran of several endangered species battles who is now working on Bay Delta conservation, the recent court decisions are likely to be the beginning of a very eventful year that could decide the fate of the delta for decades to come. In November, Isenberg's Delta Vision task force is scheduled to deliver its recommendations for the region. Another set of stakeholders, meanwhile, is working to create the Bay Delta Conservation Plan to address water-quality and habitat-restoration needs for the ecosystem. Yet another group of academic and nonprofit policy researchers chimed in earlier this year with a report that outlined five viable ways forward for the delta, including managing the estuary for environmental rehabilitation and "armoring" the levees around selected islands to ensure that the fresh water continues to flow through the delta in the event other levees give way.

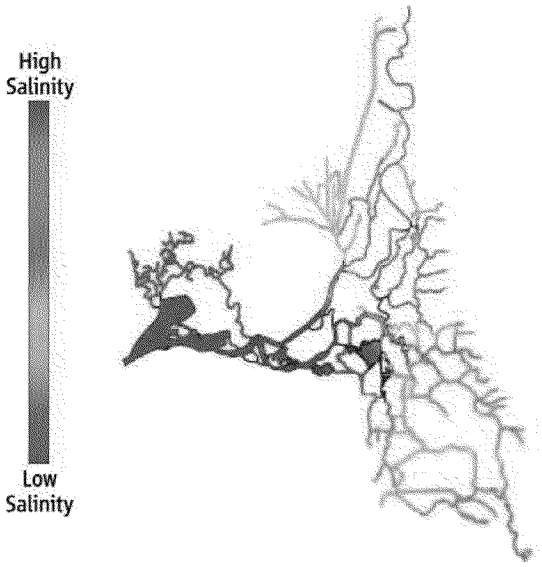
The list of recommendations will continue next year, when USFWS and BOR are expected to release their revised management plans for the delta smelt, which are likely to govern operations for the next 5 years. And finally, state officials announced this month that they intend to ask voters for a new $5.9 billion bond measure to build two new dams and begin detailed studies of a canal that would remove irrigation and municipal water from higher up the delta and channel it directly to the south delta pumps to avoid sucking fish. California voters overwhelmingly rejected a similar proposal in 1982. But Schwarzenegger recently voiced his support for the plan.

What's not clear yet is how these court decisions, ballot measures, and regional plans are likely to mesh, and whether they'll come in time to save the delta smelt. "The delta smelt will be very lucky if it makes it," says Peter Moyle, a fisheries biologist at UC Davis.

Perhaps, then, it's little surprise that interest in UC Davis's smelt-breeding program is taking off. "It's not something any fish biologist wants to do," Lindberg says. "It would be preferable to restore the natural healthy delta ecosystem. But if the population is nearing extinction, then people are willing to consider the possibility of going down that road."

–ROBERT F. SERVICE





Increased demands. Exports of water outside the delta from two pumping stations (*yellow and purple*) have soared. Low flows into the delta in August 1992 led to saltwater encroachment (*right*).

CREDITS (TOP TO BOTTOM): CALIFORNIA DEPARTMENT OF WATER RESOURCES

Published by AAAS